Vegetation Assessment in the Thompson Area Using Landsat Imagery

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VEGETATION ASSESSMENT IN THE THOMPSON AREA USING LANDSAT IMAGERY

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ABSTRACT

Inco Metals Company, Manitoba Division tested the use of LANDSAT imagery to determine vegetation changes in the area around the integrated nickel mining, smelting and refining complex at Thompson, Manitoba. Ground truthing and assessment was carried out, in cooperaton with Inco by the Environmental Management Services Branch, Manitoba Department of Environment and Workplace Safety and Health.

Major changes in vegetation cover such as vegetation removal or revegetation were accurately detected in most instances. Overestimation of vegetation decrease based on the 1978 imagery was probably caused by an abnormal rainfall event. Other misinterpretation may have been due to a lack of familiarity with local conditions. Because the methodology was designed to determine only the more obvious changes, subtle pollution-related vegetation stress, including foliage loss, was not detected.

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Thompson Vegetation Change Detection Map
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1. INTRODUCTION

In the fall of 1982, Inco Metals Company, Manitoba Division, contracted with the Ontario Centre for Remote Sensing to carry out a LANDSAT imagery assessment of vegetation cover for the Thompson area. The objectives were to examine the utility of LANDSAT imagery for defining vegetation cover changes in the area adjacent to and impacted by the Inco Thompson nickel smelter and to establish the 1973 imagery data as a basis for future vegetation comparisons. Initially, two images of the Thompson area, taken 27 July 1973 and 28 July 1978, were compared using computerized digital techniques. The final product was a composite comparison map which highlighted pixels where there was a vegetation change (increase or decrease). It was also possible to separate pre-Churchill diversion water bodies from post-diversion flooding.

In 1983, Terrestrial Standards and Studies, Environmental Management Division, Department of Environment and Workplace Safety and Health, undertook a cooperative project with Inco to assess the accuracy of the LANDSAT vegetation assessment. This included a ground truthing survey of selected sites which showed vegetation change. Personnel from Terrestrial Standards and Studies conducted the ground truthing and Inco funded the cost of helicopter charter for the survey. The survey was carried out on 13 July 1983.

Subsequently, a second comparison was initiated, based on 23 July/06 August 1983 imagery versus that from 1973 and 1978. Two change detection maps were produced from the comparisons, one documenting the five year interval from 1978 to 1983 and the other for the ten year period from 1973 to 1983.

This report outlines the results of the project to date.

2. PROCEDURES

LANDSAT imagery from 27 July 1973, 28 July 1978 and 23 July/6 August 1983 were analyzed using computerized digital techniques. The procedure was originally developed for the Sudbury area and was

described by Mussakowski (1983). The first step was to register the images to one another using well defined ground control points. Representative vegetation cover and water conditions (themes) were selected for the area and pixels from each theme were used as training sets in the computer. The computer then compared each pixel from the image to the given training sets. This classified the area into four categories: totally vegetated, partially vegetated, non-vegetated and water.

Classified images from July 1978 and July/August 1983 were compared to that of July 1973 to identify pixels which had changed with time. A composite change detection map was produced for each comparison, July 1973 to July 1978, July 1978 to July 1983 and July 1973 to July 1983. These change maps highlighted areas of vegetation increase and decrease.

The comparison maps were examined to determine whether known perturbances had been identified. Further assessment was carried out by examining recent small scale and medium scale aerial photography for evidence of vegetation change. Twenty-five areas (pixel groups) which showed vegetation change were selected for ground truthing (Figure 1). These were representative of areas where LANDSAT had detected change but where existing information did not help to diagnose the cause. The ground truthing survey was carried out by helicopter on 13 July 1983.

3. RESULTS AND DISCUSSION

The vegetation changes detected by LANDSAT image comparison for the 25 representative sites are listed in Table 1. Ground truthing observations and brief notes on the suspected cause of the vegetation change are included. Reference will be made to the three vegetation change detection maps:

Map 1: July 1973 to July 1978

Map 2: July 1978 to July 1983

Map 3: July 1973 to July 1983

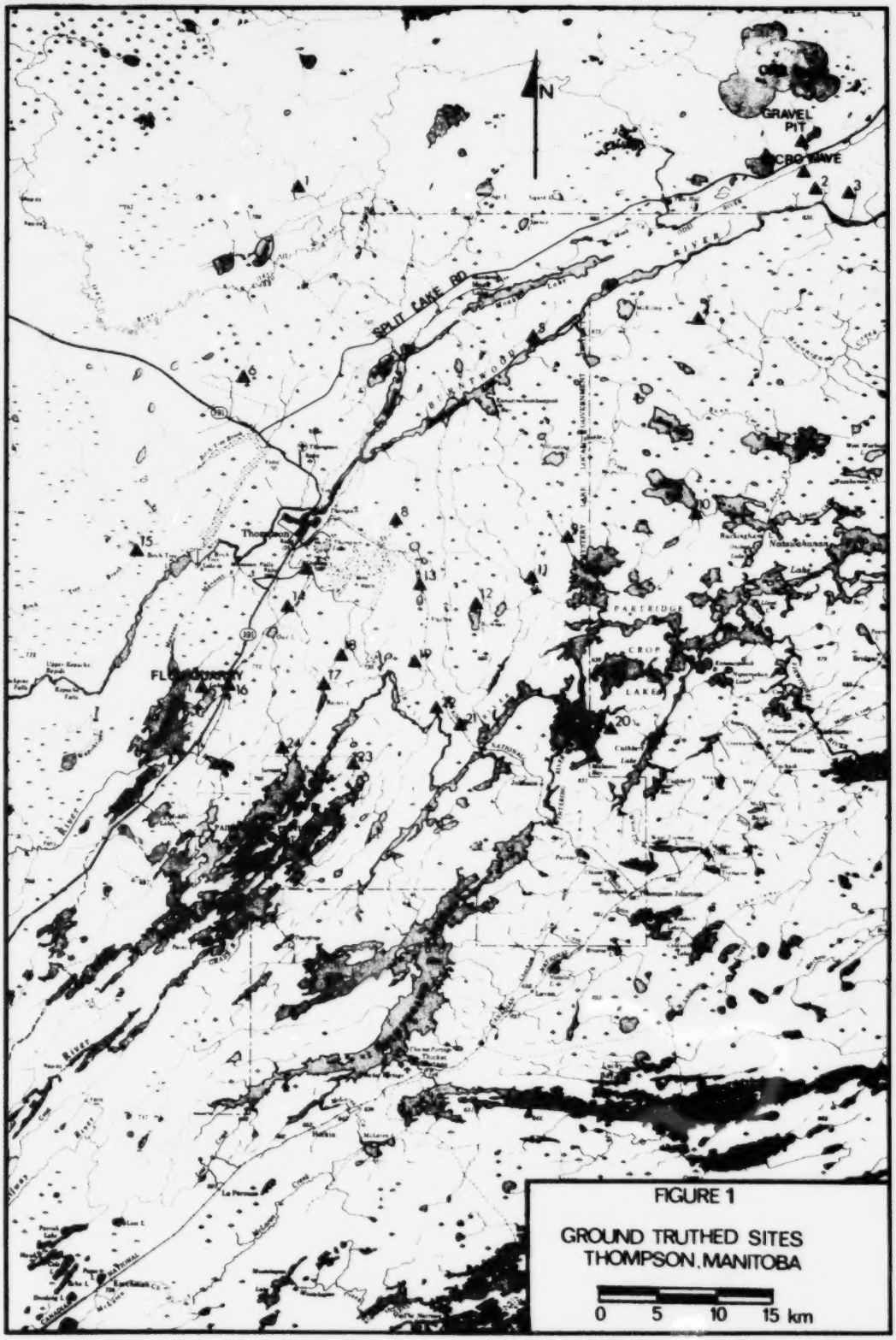

FIGURE 1

GROUND TRUTHED SITES
THOMPSON, MANITOBA

Table 1: LANDSAT vegetation change detection results plus ground truthing observations and notes on the probable cause for selected sites in the Thompson area.

Site	LANDSAT Vegetation Change Detected			Observed	Contributing	Suspected
	1973-78	1978-83	1973-83 (net)	Veg. Condition	Factor	Cause
1	decrease	increase	minor decrease	some dead trees	beaver flooding	high sediment loads July 1978
2	decrease	increase	no change	normal forest	-	high sediment loads July 1978
3	decrease	increase	no change	normal forest	-	high sediment loads July 1978
4	decrease	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978
5	decrease	increase	no change	veg. removed	Man. Hydro clearing	Hydro flooding + high sediment loads, July 1978
6	decrease	increase	no change	some dead trees	beaver flooding	high sediments loads July 1978
7	increase	no change	slight increase	new lawns near parking at Inco smelter	Inco landscaping	Inco landscaping
8	increase	increase + decrease	increase + decrease	revegetation	veg. colonization of ditch banks	veg. colonization of ditch banks
9	decrease	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978

Table 1: Continued

Site	LANDSAT Vegetation Change Detected 1973-78	1978-83	1973-83 (net)	Observed Veg. Condition	Contributing Factor	Suspected Cause
10	decrease	slight increase	no change	large aspen stand adjacent to broad vegetated marsh	-	high sediment loads July 1978
11	decrease	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978
12	decrease	increase	no change	some dead trees	impeded drainage	high sediment loads July 1978
13	decrease	increase	no change	some dead trees	herbicide drift from Hydro line/ beaver flooding	high sediment loads July 1978
14	decrease + slight increase	increase + decrease	decrease	some dead trees	beaver flooding	high sediment loads July 1978
15	decrease + water	increase	no change	some dead trees	beaver flooding/ impeded drainage	high sediment loads July 1978
16	increase + water	decrease + slight increase	increase	revegetation of borrow pits	veg. colonization of borrow pits	veg. colonization of borrow pits + high sediment loads July 1978
17	decrease	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978
18	decrease + water	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978

Table 1: Continued

Site	LANDSAT Vegetation Change Detected			Observed	Contributing	Suspected
	1973-78	1978-83	1973-83 (net)	Veg. Condition	Factor	Cause
19	decrease	increase	no change	some dead veg. with sedge regrowth	abandoned beaver pond	reveg. of abandoned pond + high sediment loads, July 1978
20	decrease	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978
21	decrease	increase	no change	some dead trees	beaver flooding	high sediment loads July 1978
22	decrease	increase	no change	dead trees	beaver flooding/ culvert blockage and/or culvert too high	high sediment loads July 1978
23	decrease + water	increase	no change	some dead trees	beaver flooding/ nat. drainage impairment	high sediment loads July 1978
24	decrease + water	slight increase	no change	some dead trees	beaver flooding	high sediment loads
Flux Quarry	decrease + water	slight increase	decrease + slight increase	disturbed site	quarry mining	quarry mining
Orr L. micro wave tower	not shown	decrease	decrease	vegetation clearing	site maintenance	site maintenance of microwave site

Table 1: Continued

Site	LANDSAT Vegetation Change Detected			Observed	Contributing	Suspected
	1973-78	1978-83	1973-83 (net)	Veg. Condition	Factor	Cause
Orr L. gravel pit	decrease	increase	decrease	vegetation clearing	gravel pit excavation	sporadic development of gravel pit
ManFor road	no change	no change	no change	vegetation clearing	access road for logging	should show as vegetation decrease
Odei River	decrease	increase	no change	normal forest	small size relative to LANDSAT resolution	high sediment loads July 1978
Taylor River	decrease	increase	no change	normal forest	small size relative to LANDSAT resolution	high sediment loads July 1978

In addition, photos in slide format of most of the selected sites are in the author's files, but are not referenced specifically in this report.

The ground truthing was done in July 1983, five years after the 1978 LANDSAT image was taken and just prior to the 1983 imagery. The notes and photos from the 1983 ground truthing survey were useful in confirming the present vegetation conditions at the sites but it was difficult to evaluate the 1978 vegetation condition. Consequently, diagnosis of the cause of the vegetation changes which were detected on the 1973 to 1978 map could not be confirmed.

3.1 Vegetation Increase

Three areas representing LANDSAT detected vegetation increase (sites 7, 8 and 16) were included in the ground truthing survey. Site 7 was depicted as two large rectangular areas in which vegetation increase had occurred. These corresponded to the newly landscaped areas east of the main Inco complex at T1. Site 8 coincided with the drainage ditch at the north outlet from Inco's tailings pond where natural revegetation of the banks is occurring. Although the vegetation cover was sparse in 1983, it must have been significant enough to register on the LANDSAT imagery. Site 16 was also accurately classified; a limited vegetation cover has developed over the disturbed soil of borrow pits. The ditches and borrow pits along the oldest stretch of the Split Lake Road also showed signs of revegetation (vegetation increase) on the 1978 to 1983 map.

3.2 Vegetation Decrease

Some of the vegetation decrease which was identified on the LANDSAT comparison maps resulted from known perturbances. For example, Inco's flux quarry and the gravel pit near Orr Lake were both accurately represented as vegetation decrease areas. Similarly, vegetation loss along Provincial Highway #391 both south and north of Thompson was accurately delineated. Right-of-way maintenance and road

repairs were responsible for the impact. The disturbance caused by the construction of the Split Lake Road was also well represented on the maps. In addition the 1978-83 map indicates considerable surface disturbance at the Thompson Municipal Airport; it was probably caused by site maintenance and/or construction. The microwave tower site near Orr Lake registered vegetation decrease between 1978 and 1983 (1978-83 map) but there was no change on the earlier 1973-78 map. A possible explanation for this is that the site may have been well vegetated at the time of the 1973 and 1978 LANDSAT imagery but that site maintenance such as herbicide treatment or vegetation clearing could have been carried out in the subsequent five year period.

There was one area of known vegetation loss which was not detected on the LANDSAT map. In 1982, ManFor cleared a right-of-way for a forestry road between PTH 391 south of Thompson and the Canadian National Railway spur line to Thompson. This should have shown on the 1978-83 and 1973-83 maps. Reasons why it was not detected may have been because it was too narrow relative to the LANDSAT resolution, or the appropriate theme was not entered into the computer. Based on our observations in 1983, some parts of the right-of-way should have been wide enough to be detected. Therefore we are led to assume that the error resulted from an oversight by the image analyst in not programming the computer with the appropriate theme.

Twenty-two additional sites were ground truthed to examine the cause of the vegetation decrease detected by the 1978 LANDSAT imagery. All sites were along stream courses and many were associated with beaver impoundments. However, although some trees had been flooded out around the periphery of the beaver ponds, the vegetation loss seemed to be relatively small in comparison to areas registered on the 1973-78 vegetation change detection map. Similarly, anthropogenic impacts could account for some of the vegetation loss at sites 5, 13 and 22, but the affected areas appeared to be much smaller than the LANDSAT vegetation change maps showed. At site 5, Manitoba Hydro had carried out some shoreline clearing in anticipation of

increased flow in the Burntwood river due to the operation of the Churchill Diversion. However, other shoreline clearing was not identified by LANDSAT. At site 13, some vegetation damage was caused by herbicide drift adjacent to a Manitoba Hydro transmission line. At site 22 incorrect elevation of a culvert through the railroad grade caused some flooding damage to a black spruce stand. However, once again, the actual tree loss at these sites (5, 13 and 22) was minimal and therefore, given the LANDSAT resolution, was probably not detectable. All three sites did have a common link with the other vegetation loss sites in that they were associated with streams.

Our suspicion that the vegetation loss may have been too small to be detectable was confirmed to some extent when we found that the 1978-83 and 1973-83 maps did not detect the loss. We also began to question whether there may have been errors in the 1978 classification because vegetation increase was detected at the ground truth sites on the 1978-83 map but the 1973-83 comparison showed that there had been no change in vegetation cover over the ten year interval. Nevertheless, there must have been an anomalous condition at these sites on 28 July 1978 which produced a spectral response corresponding to unvegetated soil. Having examined all available data, we believe that the unvegetated signature was probably produced by sediment laden (muddy) water in the streams and beaver ponds. There are four independent pieces of data which support this theoretical explanation:

a) rainfall was much higher during the five days prior to the 1978 LANDSAT image than prior to the 1973 and 1983 images.

b) the 1973-78 map registered vegetation decrease along the Odei and Taylor Rivers.

c) at most sites, vegetation decrease on the 1973-78 map reversed to vegetation increase on the 1978-83 map but over the ten year interval, 1973-83, no change was detected. This also applied to the Odei and Taylor Rivers.

d) there was a large increase in the number of small ponds between 1973 and 1978 (shown in light blue; Water-1978) but they had disappeared again by 1983 because they do not show on the 1978-83 or 1973-83 maps.

(a) Total rainfall during the five days prior to 28 July 1978 was 62.2 mm (Atmospheric Environment Service 1978). By comparison, prior to 27 July 1973, there were ten days with virtually no rainfall - only 0.25 mm on 25 July 1973 (Atmospheric Environment Service 1973). Similarly over the 6 day pre-image time period before 23 July 1983, there were only 7.6 mm of rain (Atmospheric Environment Service 1983). The high rainfall in July 1978 probably caused flooding and may have increased sediment loads in the streams.

(b) The 1973-78 vegetation change detection map registered vegetation decrease along the Odei and Taylor Rivers but when the area was ground truthed in July 1983, there was no evidence of tree or shrub mortality on the river banks. We suspect that high sediment loads in the rivers resulted in spectral characteristics which were mistaken for unvegetated terrain. Larger rivers did not fall prey to this misclassification because of greater dilution.

(c) Vegetation decrease was detected at selected sites on the 1973-78 comparison maps even though the vegetation loss was probably too small to be detected by LANDSAT. However, the condition was reversed over the subsequent five year (1978-83) period and there was no vegetation change detected over the ten year (1973-83) period. Because the same pattern (that is, decrease then increase) occurred along the Odei and Taylor Rivers, we suspect that the 1973-78 vegetation decrease may have had a common cause, namely a temporary anomaly created by excessive runoff carrying high sediment loads.

(d) The scenario is also supported by the large increase in the number of new small water bodies (ponds) in 1978. Most of these had disappeared in the 1978-83 assessment. This confirms that the heavy rainfall prior to 28 July 1978 had caused temporary flooding and further supports the theory that much of the 1978 vegetation decrease was probably sediment laden runoff water which had collected in beaver impoundments.

3.3 Sensitivity of Method

It is apparent that the usefulness of this method of LANDSAT image analysis for detecting vegetation change, is limited. Since the method was developed to highlight the more obvious changes (Mussakowski 1983), it may not be sensitive enough to detect chronic injury or stress to vegetation caused by sulphur dioxide or heavy metals. Chronic injury is usually characterized by subtle changes in spectral reflectance but Landsat imagery may not have the sensitivity to detect those changes. Higher resolution images such as false-colour infrared photography have been interpreted in an attempt to detect air pollutant damage in the Thompson area (Phillips and Slaney & Co. 1981, Wotton and Hogan 1981). Even the large scale photography used by Phillips and Slaney & Co. (1981) could detect only minimal evidence of changes in spectral reflectance. Since strong spectral signals of pollutant stress are not found in the Thompson area, we doubt that the computerized detection of vegetation changes from LANDSAT imagery, would be useful in detecting short-term effects of sulphur dioxide and heavy metals.

Dottavio and Williams (1983) were able to classify insect defoliation on the basis of the ratio between the infrared (band 7) and red (band 5) response on LANDSAT imagery. However, defoliation of less than 30 percent could not be discerned from the normal forest. Since studies have found only minor defoliation in the Thompson area resulting from smelter emissions (Phillips and Slaney & Co. 1981), even this more precise image analysis technique probably could not be used to map impact zones.

Acute changes such as foliage burn, advanced chlorosis or severe loss of foliage may be detectable on LANDSAT imagery. Also, if major changes in vegetation community composition occurred over the long term, LANDSAT detection might be possible. One must keep in mind though that the imagery is based on the average spectral reflectance of individual pixels and changes can only be detected if there is enough vegetation increase or decrease in a given pixel to produce a quantifiable shift in that average.

Therefore, vegetation changes identified by the LANDSAT comparison technique were not attributable to Inco's smelter emissions. However, this must not be interpreted to mean that there is no vegetation damage in the Thompson area which was caused by smelter emissions. Chronic vegetation damage has been observed in the area close to the smelter (Phillips and Slaney & Co. 1981, Wotton and Hogan 1981) but this LANDSAT assessment was merely not sensitive enough to detect it.

4. CONCLUSIONS

The LANDSAT vegetation assessment was accurate for certain classes of vegetation change such as soil disturbance and removal associated with road construction and gravel and rock quarries. In addition, revegetation of previously disturbed sites was accurately identified even when the vegetation cover was relatively sparse.

A forest harvesting operation initiated during the 1978 to 1983 period was not depicted on the change maps; the reason may have been that training sets for that category were not provided to the computer.

Errors of commission were common on the 1973 to 1978 change detection maps; vegetation decrease was identified at numerous wetland areas, especially beaver ponds at the mouths of small creeks. Vegetation decrease was also common along the Odei and Taylor Rivers. It is believed that high runoff caused by heavy rainfall prior to the 1978 LANDSAT imagery may have produced high silt loads in the small creeks. The silt laden water must have had a spectral reflectance corresponding to unvegetated soil and that resulted in the apparent misclassification.

Since the methodology was developed to show the more obvious changes in vegetation cover, it does not appear to be sensitive enough to assess subtle vegetation damage caused by air pollutants such as sulphur dioxide and heavy metals. Therefore, no conclusive statements were possible with respect to the presence or extent of vegetation damage from smelter emissions.

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